SUSY small angle electron tagging requirements

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LAL-Orsay

MDI workshop - SLAC
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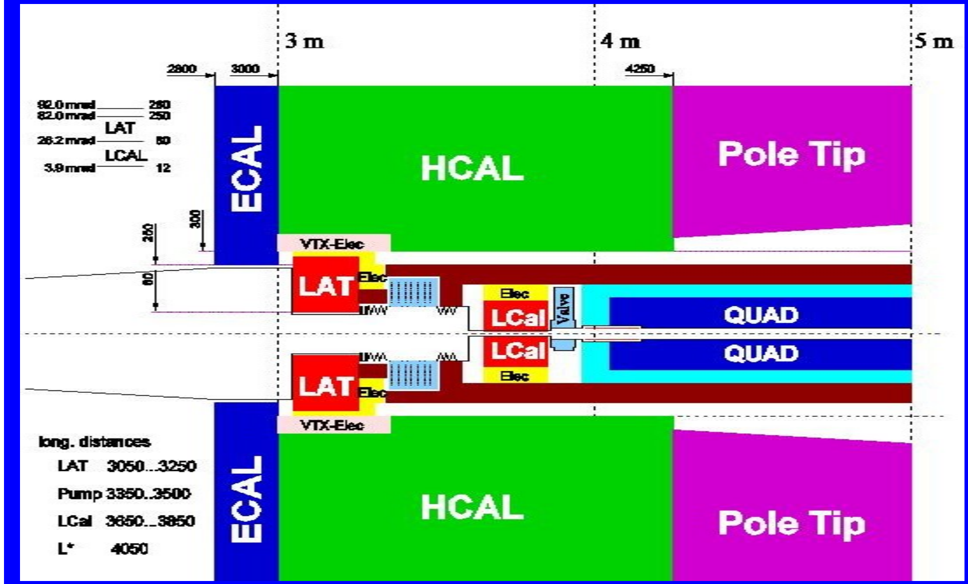
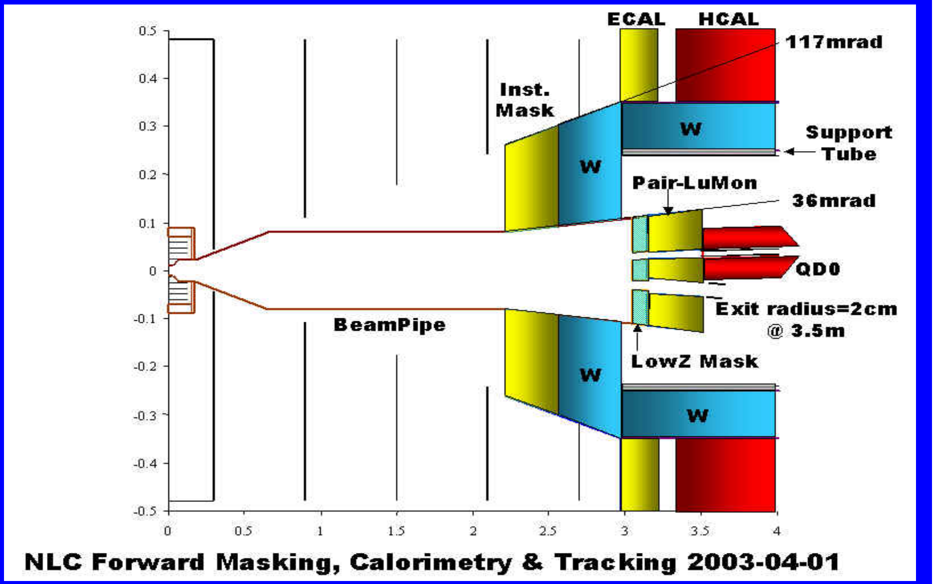
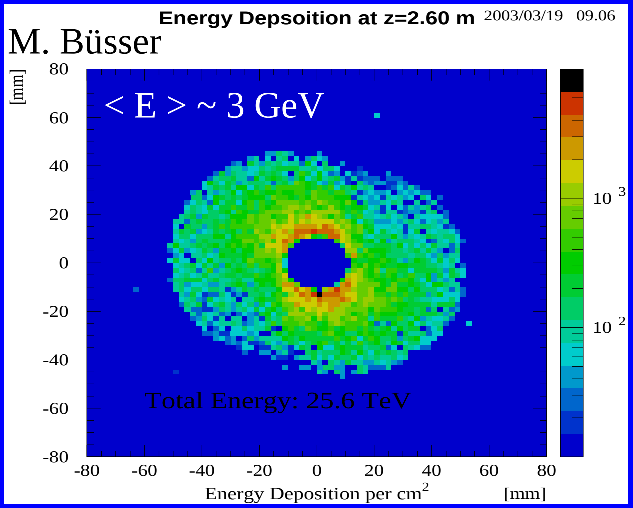
With M. Berggren, F. Richard, Z. Zhang + DESY colleagues

Instrumentation in very forward region

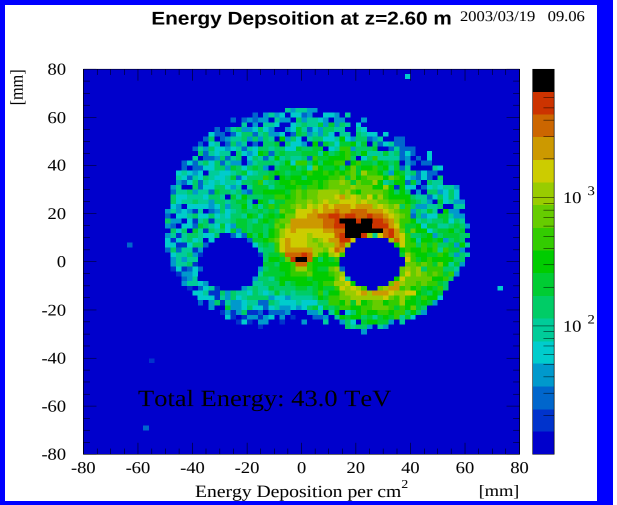






e.m. tagging down to ~ 5 mrad :

- importance ?
- feasibility ?

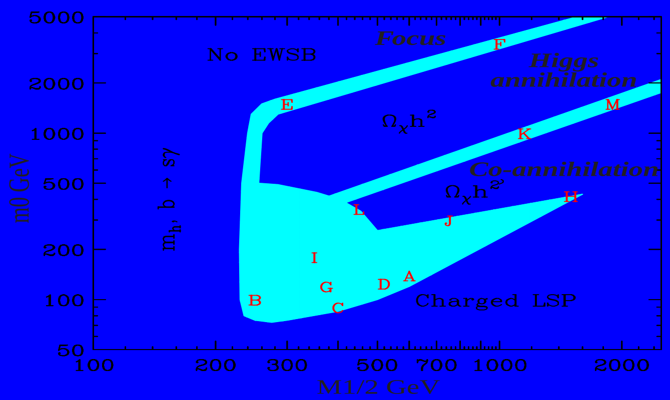


Dark Matter $\leftrightarrow$ SUSY $\leftrightarrow$ LHC + LC

WMAP cosmic microwave background radiation measurement lead to :

$\Omega_{\text{total matter}}\, h^2 = 0.134 \pm 0.006$ and $\Omega_{\text{baryon}}\, h^2 = 0.023 \pm 0.001$ PDG July 2004

$\rightarrow$ mSUGRA with WMAP constraint $0.094 < \Omega_{DM}\, h^2 < 0.129$ (2 sigma)



M. Battaglia et al. Eur.Phys.J.C33:273-296,2004

Model	A'	B'	C'	D'	E'	F'	G'	H'	I'	J'	K'	L'	M'
M1/2	600	250	400	525	300	1000	375	935	350	750	1300	450	1840
m0	107	57	80	101	1532	3440	113	244	181	299	1001	303	1125
$\tan\beta$	5	10	10	10	10	10	20	20	35	35	46	47	51
μ	773	339	519	−663	217	606	485	1092	452	891	−1420	563	1940
$m\chi$	242	95	158	212	112	421	148	388	138	309	554	181	794
me_R, μ_R	251	117	174	224	1534	3454	185	426	227	410	1109	348	1312
$m\tau_1$	249	109	167	217	1521	3427	157	391	150	312	896	194	796
$\tau_1 - \chi$	7	14	9	5	1409	3006	9	3	12	3	342	13	2
$\Omega_{DM} h^2$	0.09	0.12	0.12	0.09	0.33	2.56	0.12	0.16	0.12	0.08	0.12	0.11	0.27

$\rightarrow$ for quasi mass-degenerate neutralino (χ) and slepton (τ), both $\chi\chi$ and $\chi\tau$ (co-)annihilations combine to regulate the amount of relic DM

$\rightarrow$ $N(\tau) / N(\chi) \sim \exp(-20\Delta m/m) \sim 1 \Rightarrow \Delta m < 10$ GeV and $m < 400$ GeV

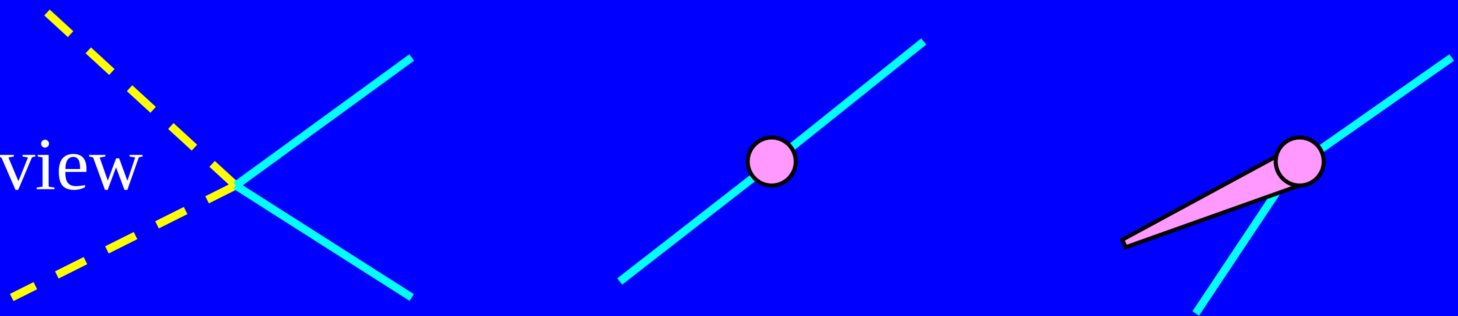
$\rightarrow$ attractive mechanisms also beyond mSUGRA D.Hooper et al. Phys.Lett.B562(2003)18

Detection of $\tilde{l} = \tilde{\mu}, \tilde{\tau}$ sleptons for small Δm

P.B. et al. hep-ph/0406010

signal	major background : $\gamma\gamma$
$ee \rightarrow l\, \chi^0\, l\, \chi^0$	$ee \rightarrow (e)(e)\, l\, l$
$\sigma \sim 10$ fb	$\sigma \sim 10^6$ fb

Transverse view



Near threshold $E_l = \gamma\,(1 \pm \beta)\,(m_{\tilde{l}}^2 - m_{\chi}^2) / 2\, m_{\tilde{l}} \sim \Delta m\, \gamma\,(1 \pm \beta)$

$\gamma\gamma$ background $\rightarrow$ must tag spectator electron (e.g. for Δm=5 Gev):

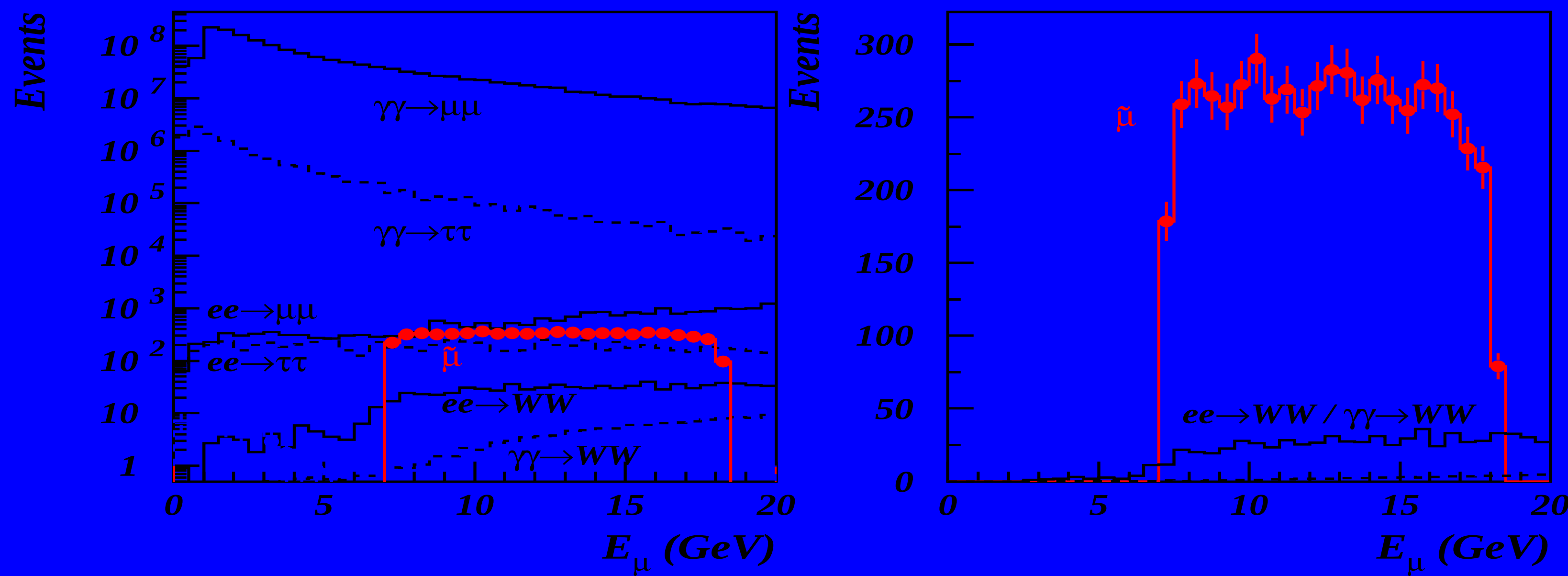
$\theta \sim \Delta m\, \gamma\,(1 - \beta) / E_{beam} \times$ factor $\sim$ 5-10 mrad (factor $= 1 < 1$ for μ τ)

Preliminary $\tilde{\mu}$ result

P.B. et al. hep-ph/0406010

benchmark point D' with $\Delta m_{\tilde{\mu}-\chi}$ = 12 GeV

After requiring N_μ=2 — Normalized for $L=500 fb^{-1}$



signal efficiency ~ 80% — spectrum end-points preserved

Mass extraction from endpoints : $\delta m_{s\mu}$= 0.18 GeV and δm_χ = 0.17 GeV

Δm = 12 GeV $\Rightarrow$ assumed tagging down to θ ~ 25-30 mrad

Preliminary $\tilde{\tau}$ results

P.B. et al. hep-ph/0406010

H.-U. Martyn hep-ph/0408226

benchmark point D’ with $\Delta m_{\tilde{\tau}-\chi} = 5$ GeV

More difficult → Missing energies from neutrinos,
→ Very soft final state
→ electron tagging down to $\theta \sim 5$ mrad

Two complementary strategies :

i. For large signal cross section and $2m_{stau} << E_{cm}$
→ end-point method

ii. For small signal cross section and $2m_{stau} \sim E_{cm}$
→ event counting method

Main selection cuts for $\tilde{\tau}$

Z. Zhang

1. Veto energetic forward electrons/photons
2. Number of charged tracks : 1 or 3 prongs, no 2 muons, charge conservation
3. $15^o < q_{thrust} < 165^o$, acoplanarity angle $< 160^o$
4. $P_{max} < 7$ GeV, $P_{Tmiss} > 2.5$ GeV
5. ρ_T : P_t sum w.r.t. the thrust axis in transverse plane to the beam > 2.75 (or 2) GeV (P_{Tmiss} dependent)
6. Azimuthal cut on ρ_T in the case of 20mrad crossing-angle

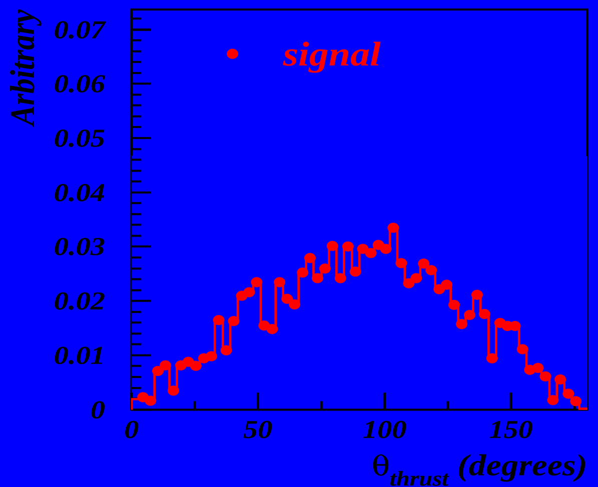
Assumed ideal reconstruction in detector acceptance (modeled in SGV)

Assumed ideal electron/photon veto down to 3.2mrad for $P_t > 0.8$ GeV

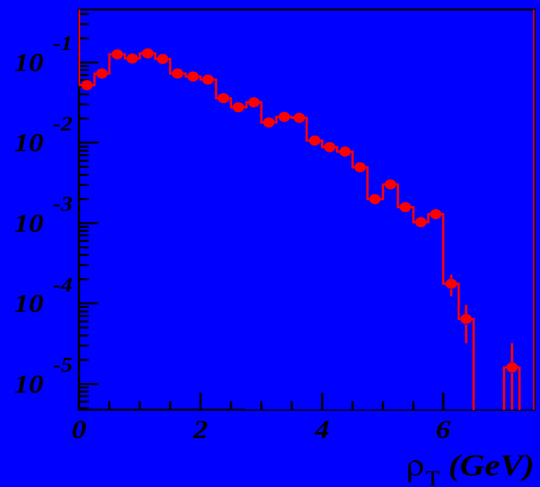
Preliminary $\tilde{\tau}$ result

P.B. et al. hep-ph/0406010

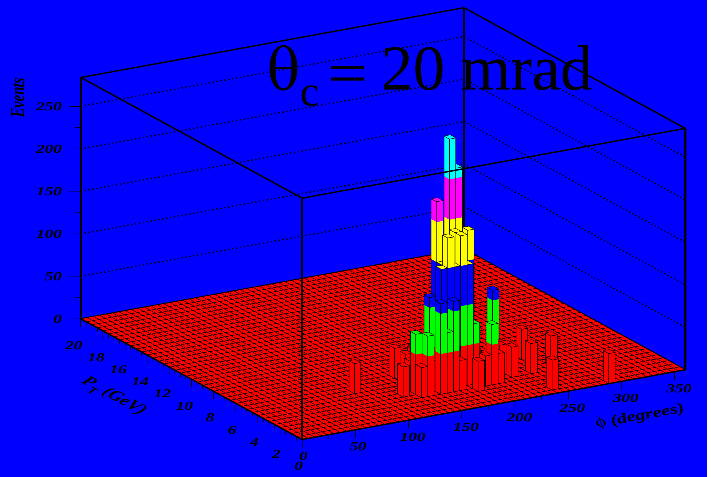
benchmark point D' with $\Delta m_{\tilde{\tau}-\chi} = 5$ GeV



Thrust axis angle in 3-dim



Σ P_T wrt thrust axis in the transverse plane



Azimuthal dependence of the transverse momentum

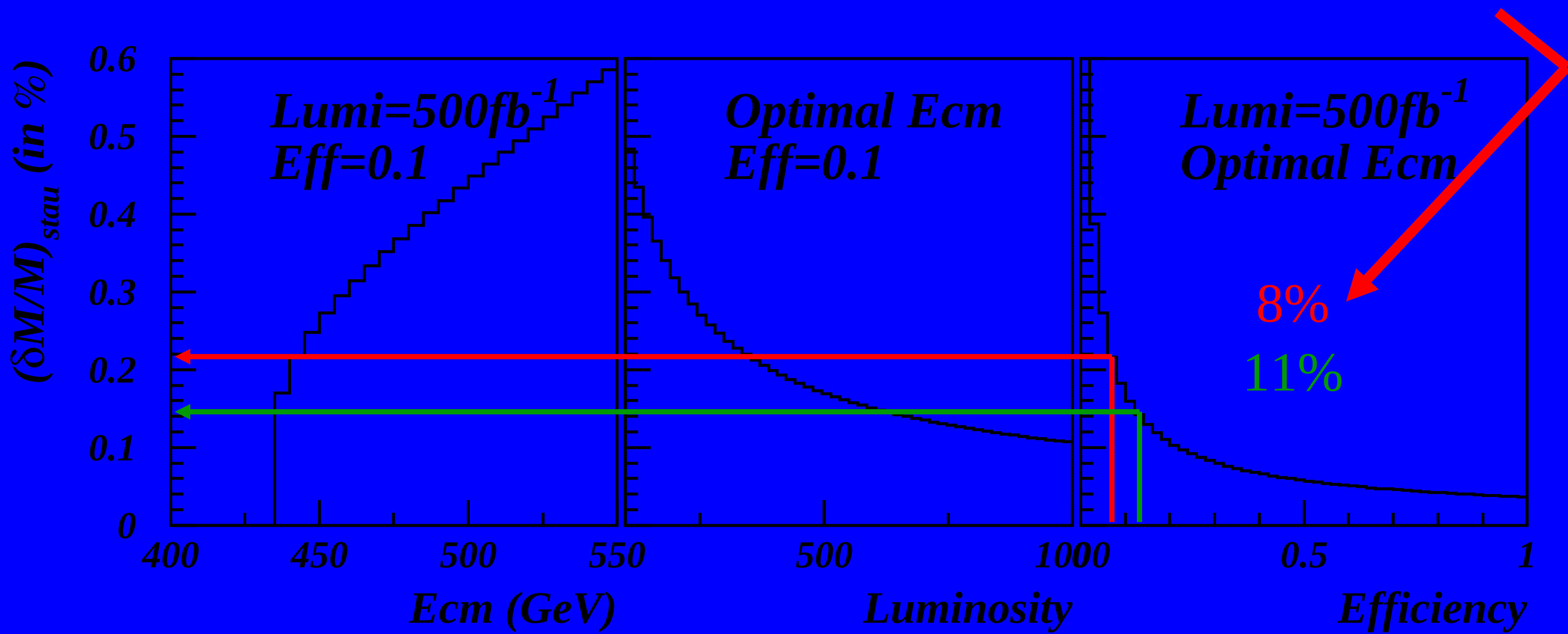
Moderate effect of 2nd hole after additional cut

	head-on	crossing-angle
efficiency	~ 11 %	~ 8 %

Luminosity, E_{CM} and efficiency optimization

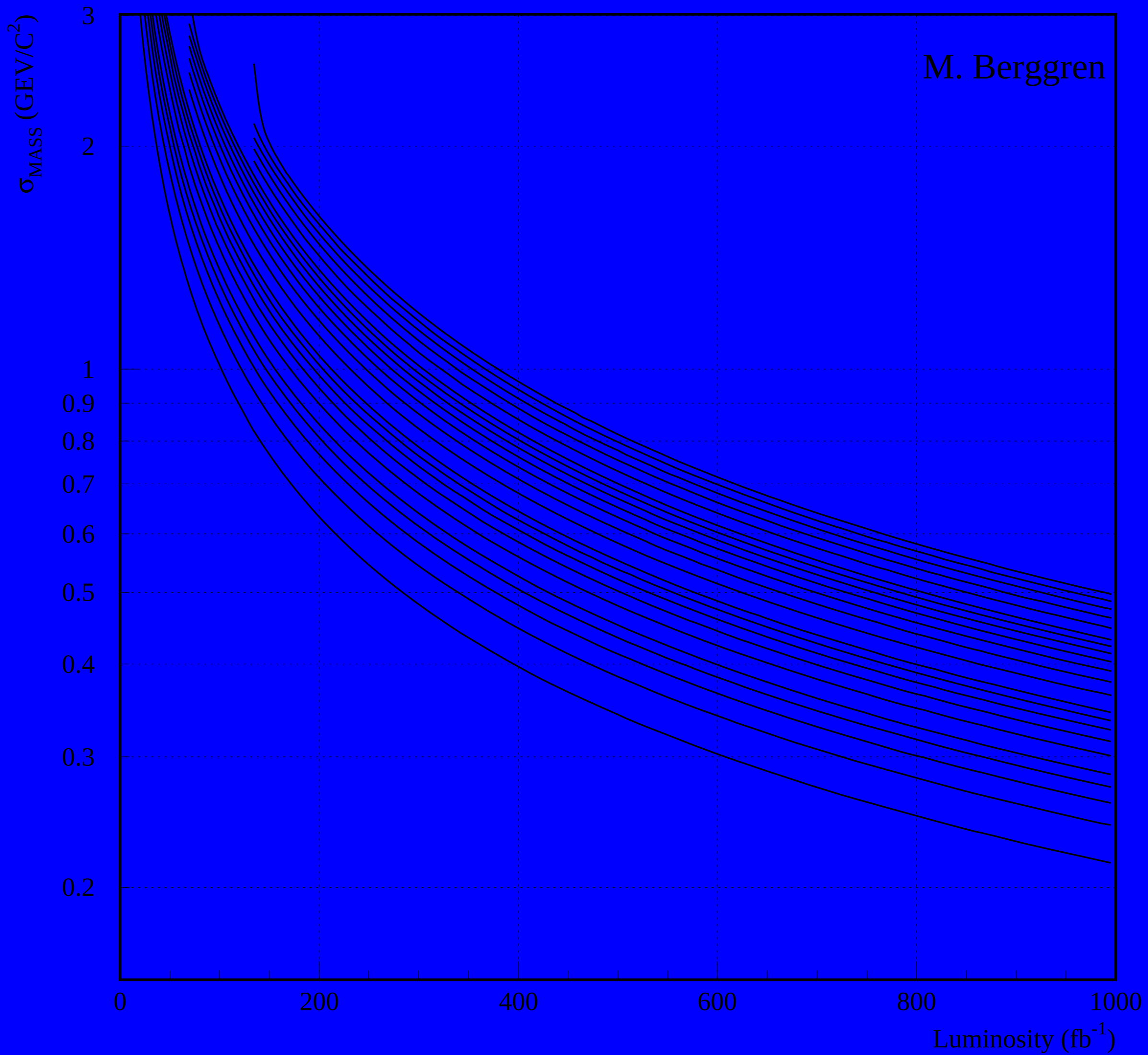
benchmark point D' with $\Delta m_{\tilde{\tau}-\chi} = 5$ GeV

$\tilde{\tau}$ mass precision wrt efficiency **effect from 2nd hole only**



Relative $\tilde{\tau}$ mass precision from cross-section measurements near the production threshold with negligible background

Mass measurement in case of background



bkgd events

100

20

7

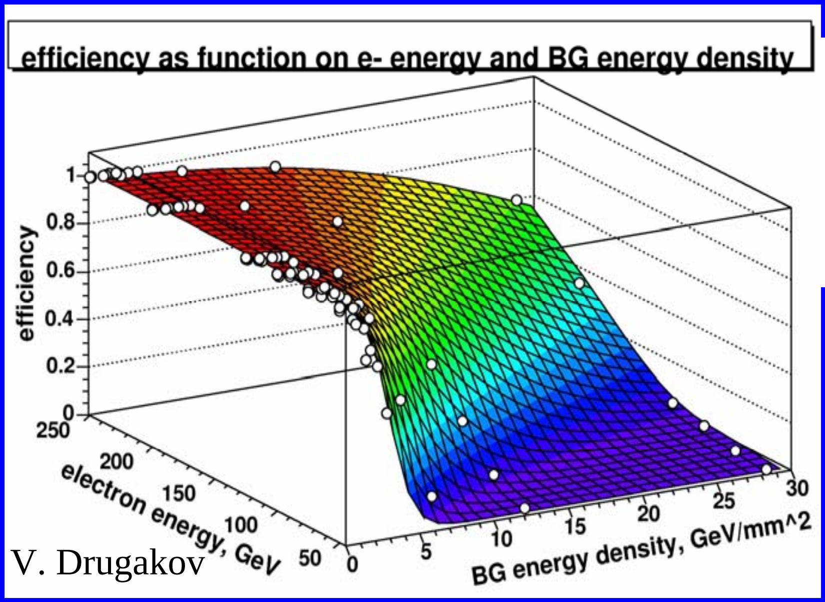
1

Mass precision degrades when background contribution increases

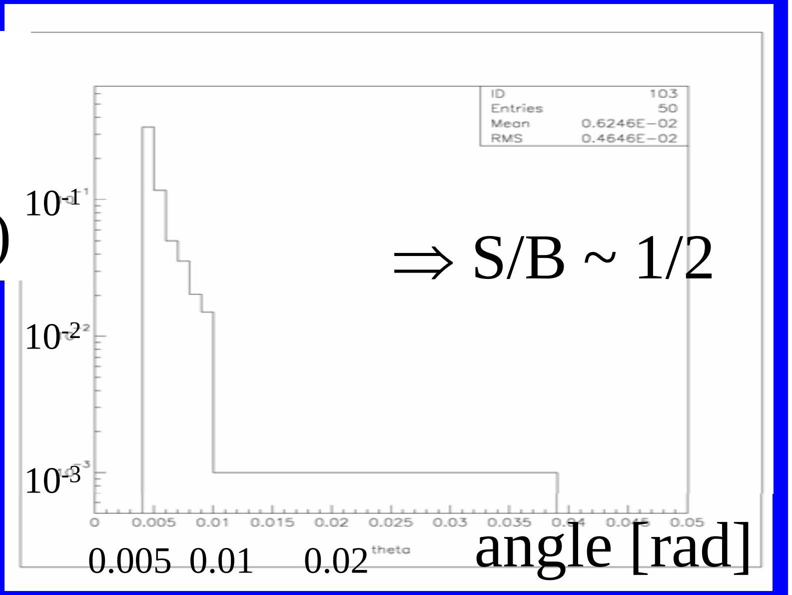
Veto efficiency & analysis cut optimization essential

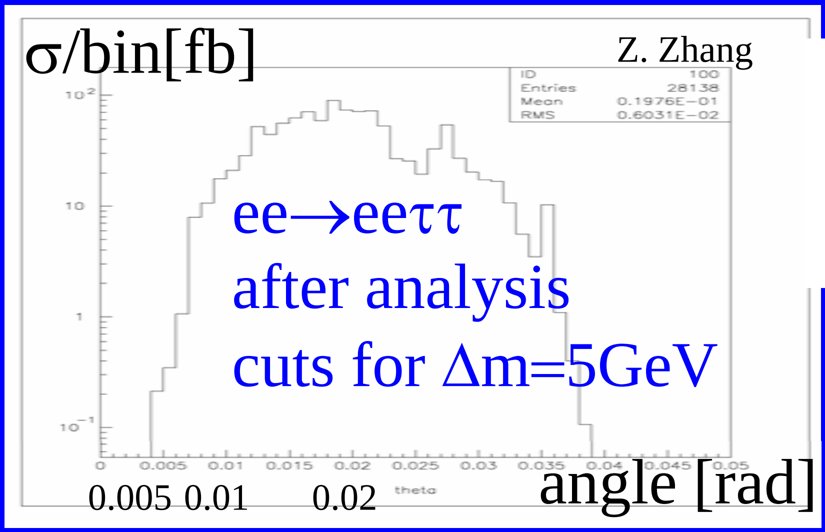
High integrated luminosity will always help

Tagging used & needed (preliminary examples)

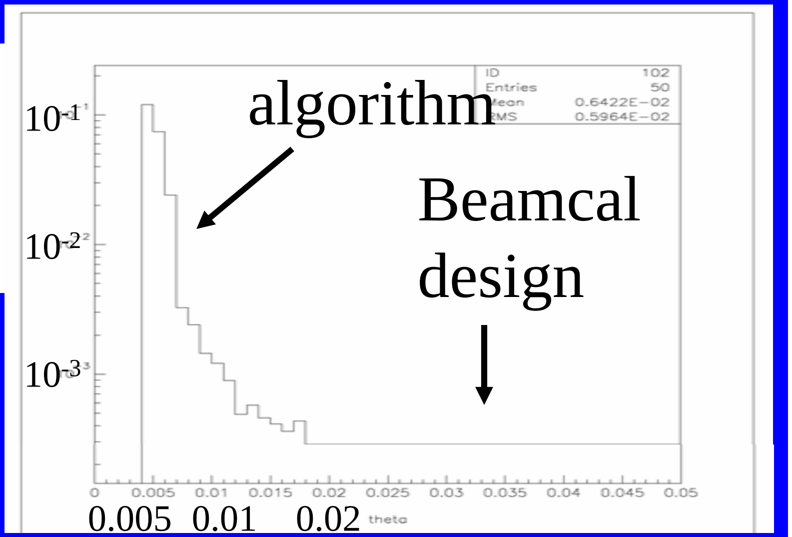


rejection
obtained
(200 GeV)





rejection
needed for
S/B ~ 1



Simplifying assumptions, caveats → future work

1. Assumed 200 GeV electrons only → also low energy tail
2. Did not use all info → hard cases often accompanied by HE photon
3. Gain by specializing algorithm for HE electrons
4. Energy reconstruction and longitudinal distribution not fully used
5. Include (lower energy) em objects from Comptons in veto algorithm
6. Interpolation underestimates efficiency (limited statistical precision)
7. Muons/hadrons within the shower are not simulated
8. …

V. Drugakov, W. Lohmann

Starting program to compare capabilities with respect to LC / MDI parameters (besides BeamCAL itself)

Min.radius – L* – B field – crossing-angle (+ serpentine) – N_{bunch} – E_{CMS}

Criteria $\begin{cases} \text{rejection} = f\ (\text{angle}) \\ S/B \text{ in } \tau \text{ with } \Delta m = 5 \text{ GeV} \end{cases}$

Summary and conclusions

1. Neutralinos and sleptons with small mass differences can be measured at the ILC
2. Important complementary to LHC
3. Link to cosmology : Planck constraints $\rightarrow$ 2 %
4. reach (m, Δm) / precision depend critically on very forward electron rejection :10^{-1} - 10^{-3} $\rightarrow$ 5-10 mrad
5. Program to compare capability wrt different LC and MDI parameters $\rightarrow$ Snowmass'05
6. Program to design, prototype and test BeamCAL
7. Check other ILC physics requiring forward veto